# STUDIES ON SEASONAL ANAEMIA IN THE ROTTNEST ISLAND QUOKKA, *SETONIX BRACHYURUS* (QUOY & GAIMARD) (MARSUPIALIA; MACROPODIDAE)

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## Summary

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A population of the quokka, a small marsupial, lives on Rottnest Island, which lies off the west coast of Australia. Most of the annual rainfall occurs during the winter and there is a summer drought. During the summer no free water is available to quokkas living on the West End of Rottnest I. Water is available at this time to quokkas living in the centre of the island. The population of quokkas undergoes an annual weight cycle and an associated cycle in haematological condition. They are at their peak weight and their blood counts are normal at the end of spring. By the end of summer, there has been a large decrease in body weight and an associated decline in haematological condition. The factors contributing to the cycle are reviewed. Depressed food intake during the summer leading to inadequate nutrition is probably the major cause of the observed cycle.

## Introduction

Rottnest Island, lying west of Fremantle, Western Australia, was named by de Vlamingh in 1696 after the small wallaby that was abundant there at that time and which he mistook for a rodent. This wallaby, the quokka *Setonix brachyurus* (Quoy & Gaimard), is still abundant on the island (Hodgkin & Sheard 1959). The total area of Rottnest is 1900 ha, of which 200 ha is covered by salt lakes. Fresh-water seepages occur on the shores of several of these and are important as water sources for the quokkas during the summer.

The island is 9.7 km long and 4.8 km wide at the maximum width and the long axis is orientated roughly east-west. At 6.4 km from the eastern end, the island is constricted to a narrow neck of land some 180 m wide and further west the island broadens out to a maximum width of 0.7 km. The part of the island west of the narrow neck is known by the general name of West End. All of the salt lakes, seepages and the few fresh-water soaks are confined to the middle and eastern end of the island and none are known further west than near the main lighthouse, situated on the highest hill which is in the middle of the island.

Weather conditions on Rottnest I. are similar to those on the nearby mainland, except that annual rainfall (734 mm) is 150 mm less and maximum and minimum temperatures are less extreme. The overall pattern is one of winter rainfall and summer drought. During summer, maximum daily temperatures can be in excess of 38°C and temperatures above this figure have been recorded during November-March. Mean rainfall during the same period is 14 mm per month in November and March, 10 mm in December and February, and 6 mm in January. No free surface water is available to West End quokkas in the summer except after occasional thunderstorms when surface pools may form but quickly disappear. The season usually breaks in April when general winter rains commence. Maximum monthly rainfall occurs in June.

When Europeans first settled in Western Australia, the predominant trees on Rottnest I. (Somerville 1954) were the Rottnest pine, *Callitris preissi* Miq., ti-tree, *Melaleuca pubescens* Schau., and coastal wattle, *Acacia rostellifera* Benth. Since the establishment of a prison on the island in 1838, changes occurred in the vegetation caused by clearing, fires and overgrazing by quokkas (Storr 1963). At the present time pines have almost disappeared, wattle now occupies only a small area and ti-trees occur sporadically. The predominant

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plant association which has increased in area since settlement is a heath of *Acanthocarpus preissii* Lehm.–*Stipa variabilis* Hughes (Storr *et al.* 1959). The samphires, *Arthrocnemum arbuscula* (R. Br.) Moq., *A. halocnemoides* Nees, and *Salicornia australis* Banks et Sol., grow around the salt lakes and soaks, some of which are fringed by swordgrass, *Gahnia trifida* Labill., and the sedge, *Scirpus nodusus* Rottb., both forming a dense cover heavily utilised by quokkas. A flora list has been published by Storr (1962).

The quokka is one of the small members of the family Macropodidae. Adult females weigh from 2.5-3.0 kg and adult males from 3.5-4.5 kg. Its relationships with the rest of the group have been discussed by Sharman (1954) and Ride (1957). Moir *et al.* (1954, 1956) described ruminant-like digestion in the quokka, which has a well developed bacterial population in the fore-stomach and pre-gastric fermentation. Blood glucose and plasma volatile fatty acid concentrations are intermediate between those of ruminants and rabbits (J. Barker 1961).

Quokkas occur all over Rottnest I. but during summer those living in the central part of the island congregate in the vicinity of fresh-water seepages on the edges of the salt lakes and near the fresh-water soaks. They graze the mat of salt-water couch, *Sporobolus virginicus*, (L.) Kunth., so close that it becomes a typical 'marsupial lawn', similar to those seen in Tasmania (Ridpath 1964) and other areas of Australia. They live in high density on the eastern end of the island, under the houses used for tourist accommodation, and they are addicted garbage feeders. The smallest population probably occurs between the main lighthouse and West End. There seems to be a fairly constant population (Niven 1970)[1] living on West End, which shows local feeding movements during summer (Nicholls 1971). They do not migrate from West End to fresh-water sources during the height of summer or indeed at any time of the year (Dunnet 1962).

Work on the ecology of the quokka population on Rottnest I. commenced with a tagging programme in November 1953. The summer of 1953/54 was hot and dry and by March 1954 many quokkas were emaciated and some were dying. Research was commenced to find out why animals were dying and what factors were controlling population numbers (Waring 1956). The progress made on these problems is the main subject of this paper.

### Seasonal Anaemia

In 1954 it was found that haemoglobin concentrations of quokkas caught in the centre of the island in summer were much less than those of quokkas kept in the yards of the Zoology Department, University of Western Australia, at the same time of the year (Waring 1956). The first possibility considered was the occurrence of a seasonal deficiency of copper, cobalt or both. It was known at that time that the quokka had ruminant-like digestion (Moir *et al.* 1954, 1956), that sheep quickly die on Rottnest from copper and cobalt deficiency, and that deficiencies of both copper and cobalt in ruminants result in anaemia. By analogy, the same deficiencies might have been affecting the quokkas. Barker (unpublished) collected serum samples from animals captured at West End and at Lake Bagdad over an 18 month period. The samples were assayed for vitamin $B_{12}$ (by the Haematology Department, Royal Perth Hospital) using *Euglena* as the test organism. Mean serum vitamin $B_{12}$ concentration of animals caught near Lake Bagdad was very much greater than that of animals caught at West End at all times of the year (means varying between 2,000–4,500 pg/ml as against a mean of around 1,000 pg/ml). The West End animals showed a slight annual fluctuation with the lowest mean serum vitamin $B_{12}$ concentration in the spring and the highest in summer. None of these animals had concentrations low enough to indicate cobalt deficiency when compared to the concentrations measured in animals that had been fed very low cobalt intakes for several months (Barker unpublished).

Blood copper analyses of Lake Bagdad quokkas showed a positive correlation with haemoglobin concentration but this relationship was not found in West End quokkas. It was considered that only in the Lake Bagdad population was copper deficiency likely to exert any effect on blood parameters and then it was only likely to be one factor associated

[1] Niven presented a computer study with numbers calculated from data for the West End quokka population between 1955-63, based on Holdsworth, W.N. (1964).—Marsupial behaviour with special reference to population homeostasis in the quokkas on the West End of Rottnest Island. Ph.D. thesis. University of Western Australia (unpublished).

with the development of seasonal anaemia (Barker 1961).

Shield (1959) found that haematological counts fluctuated with season and were correlated with changes in body weight. Adult quokkas from West End and from around Lake Bagdad were in peak condition in the spring. Their body weight was maximal and their blood counts were normal. By the end of summer there was a mean decline of up to 25% in body weight and there was a similar reduction in red cell parameters. There were differences between quokkas caught in the two areas in that West End animals showed higher maxima in spring and lower minima in autumn than those from Lake Bagdad.

The possibility of disease causing the anaemia was discounted, as white cell counts were lower in the summer than in the winter, whereas it would be expected that white cell numbers would increase if disease occurred in the summer. Dehydration was not thought to be a contributing factor to the decline in condition of West End animals, as Shield (1959) had found that quokkas kept for 6 months without access to drinking water, lost weight but had increased plasma protein concentration. However, it is unlikely that West End quokkas would experience such severe dehydration. Storr (1964a) calculated that they had a daily water intake of about 130 ml gained from water contained in their plant food. Shield (1959) found that in West End quokkas, haematocrit and plasma protein concentration declined during the summer period. In a later study (Shield 1971) he found that plasma volume of field animals was unchanged throughout the year. Clearly, the field animals were not experiencing the acute dehydration seen in the yard animals that did not have access to drinking water. However, the possibility that a lesser or more chronic degree of dehydration is occurring in the field cannot be excluded and this could aggravate the quokkas' condition. As a result of his studies, Shield (1959) (Main *et al.* 1959) suggested that the quokkas were affected annually by 'severe semi-starvation', which Main (1968, p. 99) interpreted as protein deficiency.

In a study of the plants eaten by the quokka, Storr (1964a) made calculations of the nitrogen and water intakes of quokkas from different localities on the island at different times of the year. The figures he used for nitrogen requirements of male quokkas were those of Brown (1964)[2] from one adult male quokka used in two series of nitrogen balance trials. Extrapolating from this data, Storr (1964a) stated that an adult male quokka requires 0.6 g N/day to remain in positive nitrogen balance. He calculated mean nitrogen intake at different localities on the island at different times of the year and concluded that quokkas at Cape Vlamingh had a large surplus of nitrogen in winter and a varying deficit in late summer. There is no doubt that Storr's use of the data of Brown (1964) is an oversimplification: for example 3 of the 4 adult male quokkas used in a feeding trial by Calaby (1958) were in negative nitrogen balance, although their daily nitrogen intake ranged from 1.3-1.6 g N/day. The diets used by Calaby were not comparable to that used by Brown (1964).

Barker *et al.* (1974) collected blood samples from one sub-population of quokkas living on West End in spring and at the end of summer (1970/71). The weight differences between the animals in spring and autumn were marked, yet mean plasma urea concentrations were similar. The field plasma urea concentrations found by Barker *et al.* (1974) were significantly less than plasma urea concentrations found in a group of male quokkas fed on high-protein food for 3 months prior to feeding them a low-protein diet. In this experiment it was found that quokkas with a low nitrogen intake ($\approx$ 0.3 g N/day) and given water *ad lib.* had plasma urea concentration reduced to 20 mg/100 ml within four weeks. Thereafter plasma urea concentrations of most animals rose. Plasma urea concentrations of quokkas fed the same diet but with a restricted water intake, fell to 40 mg/100 ml and then remained at this concentration.

This pattern has not been found in the Kangaroo Island wallaby in a similar type of experiment (Barker *et al.* 1970). Wallabies fed on a low nitrogen diet showed a progressive fall in plasma urea concentration over a two-month period. In a group fed a similar diet but with restricted water intake, plasma urea concentrations also fell but remained higher than in the control group throughout the experiment. It seems most probable that in both the experiments with the quokka and

[2] Brown, G. D. (1964).—The nitrogen requirements of macropod marsupials. Ph.D. thesis, University of Western Australia (unpublished).

Kangaroo Island wallaby, the higher plasma urea concentration in water restricted animals is a reflection of a lowered and inadequate energy intake. Water restriction below the *ad lib.* intake results in an immediate decline in appetite and thus in dry matter intake. The actual reduction in dry matter intake appears to be correlated with the severity of water restriction compared with the *ad lib.* intake. This seems to be constant *in* individual animals though it fluctuates widely *between* individual animals.

Two isolated short-term studies have also been carried out on Rottnest I. quokkas. Herrick (1961) measured adrenal ascorbic acid concentration of Rottnest I. and experimental animals to determine changes in adrenal function during summer stress, but his results were inconclusive. Packer (1968) counted eosinophil numbers in blood samples taken from quokkas on Rottnest I. at different times of the year to determine whether changing population density caused changes in circulating eosinophils. He found no consistent trend that suggested changes at different times of the year.

### Nature of the Summer Stress

So far the only evidence of disease affecting the quokkas on Rottnest I. has come from the work of Gibb *et al.* (1966) who described the occurrence of Toxoplasmosis on Rottnest I. but only from animals captured in the vicinity of the settlement on the eastern end of the island. It is expected that other infective agents will eventually be described after a diligent search has been made for them, but very little research effort has been made in this important direction.

The key to summer survival for the quokkas on West End is probably their success or otherwise in obtaining water from their food plants. No permanent source of fresh-water is known to occur further west than the main lighthouse during the summer. However, on the night of March 22nd, 1957, the writer and Dr. E. P. Hodgkin of the Department of Zoology, observed about 20 quokkas on a narrow beach in Green Island Bay, beneath a low cliff. The animals were lined up at the water's edge and were apparently drinking sea water. From close observation it was seen that the animals were digging holes in the sand, near to the water's edge, before drinking. Water samples were taken from some of these holes and from the sea some 12 inches from where the quokkas were drinking. Analysis of the samples showed that the water sampled from the hole in the sand was much fresher than sea-water (Cl 0.51%) while that taken from the sea (Cl 1.61%) was slightly less salty than normal sea water (Cl 1.9%). Casual observation without collecting water samples would have led us to the conclusion that the quokkas were drinking sea water. As Bentley (1955) found that the quokka can maintain water balance under laboratory conditions drinking 2.5% NaCl (but not sea water) it seems reasonable to assume that animals drinking seepage water were able to maintain a positive water balance.

Although water is essential for the maintenance of fluid space, excretion and temperature regulation, one of the first manifestations of water shortage is depression of appetite. To an animal that may have to forage for suitable food over long distances and survive the stress period on a marginal diet, from an energy point of view, this could lead to a slowly worsening starvation state. The animal would gradually lose weight, become weak, and unless there was relief from a change in the season, it could eventually succumb. Storr (1964a) indicated that although quokkas which feed on *Carpobrotus* at Cape Vlamingh may get sufficient water from this plant to meet their needs, their nitrogen intake would certainly be reduced below a reasonable intake for maintenance purposes and such animals could fit into the scheme outlined above.

Water is also an essential requirement for those animals living close to freshwater sources, particularly during summer and this fact has been exploited for the capture of large numbers of quokkas (Dunnet 1956). Access to water alone, however, is not sufficient for the maintenance of constant blood parameters. Both Shield (1959) and Barker (1961) showed that in animals with access to drinking water haemoglobin concentrations fell during the summer though not as dramatically as in animals captured on West End.

Despite a great deal of work and speculation on this problem, there is still no clear-cut answer to the question of the nature of the stress experienced by quokkas during the summer and early winter. It is probable that some animals surviving summer stress, but debilitated by it, are killed off when the season breaks and they are faced with cold and wet conditions. Barker *et al.* (1974) found that 8 out of 11 quokkas that had survived for 8 weeks on a low nitrogen intake, died in 10 days when night and early morning temperatures fell over a short period.

There is a strong possibility that the population at West End faces a more severe stress than those in the central parts of the island. At West End, quokkas almost certainly face a less than adequate water intake, except for those feeding on *Carpobrotus* at Cape Vlamingh (Storr 1964a), as well as nutritional stress. Quokkas living in the centre of the island face a nutritional stress only, water being available. A water shortage at West End would result in quokkas having a decreased dry matter intake causing a lowered nutritional status leading to anaemia. If nitrogen intake of quokkas in the Lakes area becomes inadequate in summer, dry matter intake would be depressed also leading to anaemia. The nature of the anaemia developed at each area would be similar despite a different origin (Barker *et al.* 1974).

Inadequate water intake does not necessarily lead to haemo-concentration (Barker *et al.* 1974). Shield's (1959) conclusion that water intake is not limited on West End in summer was based on the results of his experiment where no water whatever was provided for the experimental animals. This situation never occurs on West End as although moisture content of food plants is reduced during summer (Storr 1964a), the reduction in water intake is not likely to be much greater than half of the *ad lib.* requirement. Shield (1971) showed that a decrease in blood volume does occur in West End animals during the autumn relative to blood volumes of West End animals measured in the spring. However, the difference was due to a reduction in red cell mass, not in plasma volume, a finding not incompatible with the thesis of a restricted water intake exerting a nutritional effect through loss of appetite.

Although the figures for nitrogen requirement of the quokka given by Storr (1964a) are too limited to be conclusive, it seems from his data that nitrogen intake at West End could be less than the maintenance requirement. However, the possibility that nitrogen shortage alone causes the debility seems remote in a complex situation, where nitrogen is likely to be only one of several components of the diet which are seasonally deficient.

### Future of the Rottnest Quokka

Despite the obviously deteriorating environment on Rottnest I., caused mainly by human activities but also affected by natural erosion, the quokka population is surviving. Some of the differences between the Rottnest I. environment and that of one area where the quokka still occurs on the adjacent mainland, have been outlined by Storr (1964b). In one way, Rottnest is totally unlike the mainland situation in that no predators are present. If they were, the population would be reduced as those animals weakened by seasonal influences would fall easy prey to a predator.

The quokka has a considerable and unique value as a natural resource and it is to be hoped that it has a guaranteed future on Rottnest I. The value of the island as a training ground for scientists has been stressed by Main (1959, 1967) and this is largely because of the occurrence there of the quokka. However, the greatest value of the quokka lies in its asset as a tourist attraction. It is to be hoped that the Western Australian Government Tourist Bureau, which controls the island, does not underrate this asset and takes positive steps towards ensuring the permanent survival of the quokka on Rottnest I.

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